COMPRESSION OF VIDEO-OTOSCOPE IMAGES FOR TELE-OTOLOGY: A PILOT STUDY

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Abstract - Aim: **This pilot study was designed to determine the maximum level of compression of digitised images of the eardrum and to develop assessment protocols.**

Methods: **The JPEG algorithm was used to compress fifteen 1.44MB images to different sizes. As an objective assessment, the RMS errors between the original and compressed images were calculated. Two assessors graded image quality and recorded their observations of clinically significant abnormalities, which were compared to a gold-standard.**

Results: **RMS error increased markedly when images were compressed beyond about 20KB, and at least 90% of the images quality were graded as being of good quality until image size went below 15KB. Agreement with the gold-standard in the identification of abnormalities was >70% for the two assessors, but there was a wide range of sensitivity and specificity values. In both cases there was no relationship with the level of image compression.**

Conclusion: **Images of the eardrum can be compressed using JPEG to about 20KB before image quality is affected, but further studies require a higher quality of original images and a well understood protocol for assessment before further conclusions can be made on effect of image compression on the ability to detect clinically significant abnormalities.**

Keywords - **Telemedicine, otolaryngology, image compression, eardrum**

I. INTRODUCTION

The otoscope is one of the basic tools of doctors and allied health workers like audiologists and nurses. It projects light into the ear canal and presents a view of the eardrum and the ear canal, allowing assessment of the outer and middle ear. Otoscopes can also be supplied with a video camera and associated image-digitising equipment. Doctors can make use of these images for diagnosis and documenting the progression of ear disease.

Just as in other areas of medicine such as dermatology, ophthalmology and radiology, the accessibility and affordability of imaging and computer equipment is now making telemedicine an attractive method for the delivery of otology health care to people in rural and remote area. In many countries, as is the case in Australia, these areas are often severely under-serviced for specialist medical care. Large population centres are many hundreds of kilometres away from resident otology and audiological services, and the task falls on local general practitioners and health workers to provide the primary care for these and other medical specialties.

Diagnosis and treatment of most ear disorders requires a clinical history and otoscopic examination with audiology if hearing loss is present. Common conditions such as otitis media and glue ear can be diagnosed utilising images of the ear, and telemedicine is a prime candidate for playing a role in improving the delivery of some aspects of ear health. Store-and-forward techniques are suitable for this, where images are captured by suitable devices, stored and then transmitted via the communication networks, to an ear specialist for assessment. However, as uncompressed images are usually well over 1MB in size, they take a long time to transmit through the telecommunication networks found in rural and remote areas. These are often slow and unreliable. Therefore, to make image transmission practical, image compression is essential, especially as image numbers increase.

The most popular algorithm used in image compression is the one developed by the Joint Picture Expert Group (JPEG), which has been deployed in almost all imaging programmes and also used in medical imaging. The algorithm breaks the images into 8 pixel by 8 pixel blocks, converts the information in the block into the frequency domain, and removes some of the higher frequency information depending on the desired level of compression. The remaining information is coded and then compacted to remove redundancy. It is especially suitable for natural image scenes, which includes medical images.

Yogesan and colleagues [1] reported transmission times of 30 minutes for uncompressed ophthalmic images, which could be reduced to some minutes with JPEG compression. Other studies into the compression of medical images have also been reported. [2-5] While the case for telemedicine in otolaryngology has been discussed [6-8] there are no published studies on the requirements for digitised images. In this paper we describe a pilot study into the compression of otology images, discuss the methods used for assessment, and propose some future studies in this area.

II. METHODOLOGY

A. Images

The Welch-Allyn VDX Video-Otoscope was used to collect the views of 15 eardrums of remote area patients seen by staff of the TVW Telethon Institute for Child Health Research, Perth. The images represented a cross section of various ear were conditions. They were stored as a 24-bit colour uncompressed bitmap file, and saved on a CDROM for transport. The file size of each image was 1.44MB.

B. Image compression

Custom written software was used to compress each of the images with the JPEG algorithm. To cover a range of

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compressions the following Q (Quality) factors were used: 100, 70, 60, 50, 40, 30, 20, 15 and 10. This produced a range of image sizes, from approximately 220KB (Q=100) to approximately 11KB (Q=10). At Q=10, the blocking artefact is seen clearly; however, it is important to cover a range of compressions levels, from where there will be no noticeable effect (Q=100) through to where compression has made the image unrecognisable from the original.

C. Image assessment – objective

All of the compressed and original images were split into their three colour channels –Red (R), Green (G) and Blue (B). A custom written program then calculated the Root-Mean-Square (RMS) Error between the original images and the various compressed images for each of the colour channels; these data were plotted against image size.

D. Image assessment – subjective

One otolaryngology specialist and a trainee assessed all the original images and a subset of the compressed images. The subset were those produced with Q-settings 15, 20, 30, 40, 50 and 60; The Q=100 images were still too large to have a beneficial impact in reducing image transmission times, and empirically there was no perceptible difference between these and the original images. The Q=10 images were of extremely low quality, and were only slightly smaller in size than the Q=15 images.

Before this assessment took place, another otolaryngologist assessed all the original images to determine the gold-standard to which the other assessment were compared. These observations included earwax, discharge, scarring of the eardrum, and perforation of the eardrum (see table 1).

Ear #	Quality (E G P U)	Ear R/L	W	D	S	P	T	A	SOM	N
LB19	P	L	Y			Y				
LB3	P	L	Y				Y	Y		
LB35	P	L	Y			Y				
LB39	P	L	Y							
LB43	P	L		Y						
LB44	G	L						Y	Y	
LB45	G	L						Y		
LB54	E	L	Y		Y		Y			
LB56	G	L	Y							
LB59	P	L			Y			Y		
LB8	G	L	Y							Y
RB30	G	R	Y	Y		Y				
RB54	P	R						Y		
RB56	G	R	Y					Y		
RB8	G	R	Y						Y	

Table 1: Gold-standard assessments. Image quality is indicated by E: excellent, G: good, P: poor or U: unsuitable. Other columns headings: W: wax in ear canal, D: discharge, S: sand in ear canal, P: perforation of the eardrum, T: tympanosclersis, A: atrophic segment/retraction, SOM: serous otitis media, N: normal eardrum. A 'Y' indicates the presence of these.

The images were presented in a random order on a computer monitor to the two assessors, who were asked to grade the image quality as E (excellent), G (Good), P (Poor) or U (Unsatisfactory) for making a clinical assessment. In normal clinical practise, more information than an image of the eardrum is used to make an assessment and diagnosis. In this study, the assessor was asked only to judge the suitability of the image for diagnosis.

They were also asked to record their observations of the ear canal and the eardrum. They were presented with a list of pathology and abnormalities they may or may not see.

Finally, the assessors also noted the ear they were viewing (right ear or left ear), and were also given the opportunity to record other observations.

The assessors were asked not to go back to previous recordings and observations in cases where they may have recognised the image, nor go back to view the previous images. This was designed to minimise the affect of memory.

After the assessments were tabulated, sensitivity and specificity were calculated to compare the assessments with the gold-standard. Sensitivity is a measure of the ability to detect correctly the presence of the condition or abnormality, while specificity is a measure of the ability to assess correctly that the condition or abnormality does not exist.

III. Results

A. Image assessment - objective

Figure 1 is a plot of RMS Error versus image size after compression of the red channel of all 15 images, showing a sudden increase in RMS Error as the image size falls below about 20kB. The data from the green and blue channels have a similar distribution and trend, and are not plotted. The difference in the effects of compression on the three colour channels is shown in Figure 2, which plots the average image size of each channel for each Q-value, against the average RMS Error. It shows that the RMS Error is greatest in the red channel and least in the green channel.

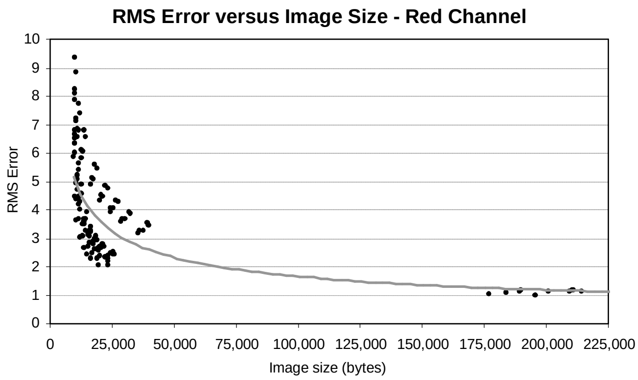


Figure 1: The RMS Error for each compression level; 15 images, with a power series curve fit.

B. Image assessment - subjective

The assessment of image quality after image compression is summarised in figure 3; the left column shows the gold-standard assessment. It shows that the quality was in most cases graded as 'Good' or better until the two highest compressions. Figure 4 plots the percentage of ears correctly

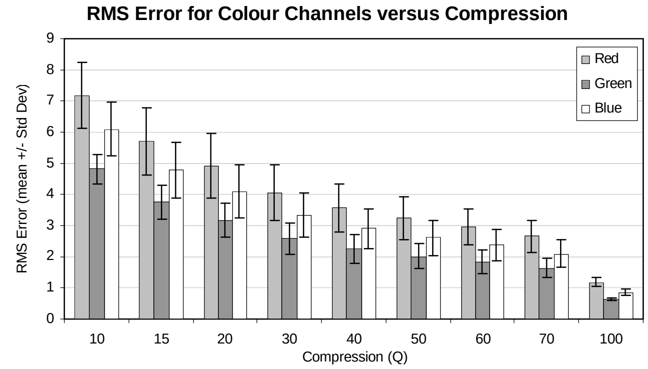


Figure 2: The average RMS Error +/- standard deviation for each Q-value for the three colour channels, where the image size at each Q-value is averaged.

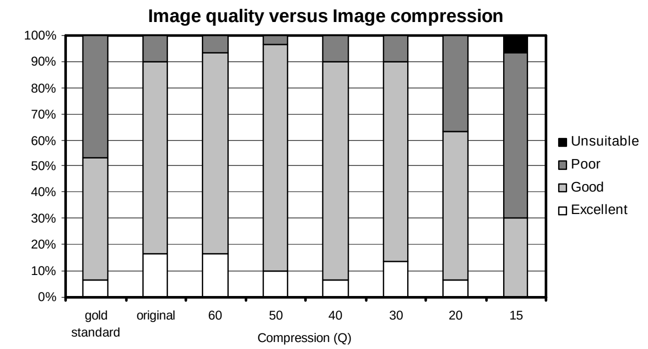


Figure 3: Image quality as assessed by the two assessors (averaged) for the different compression rates; the gold-standard assessment is shown in the left bar.

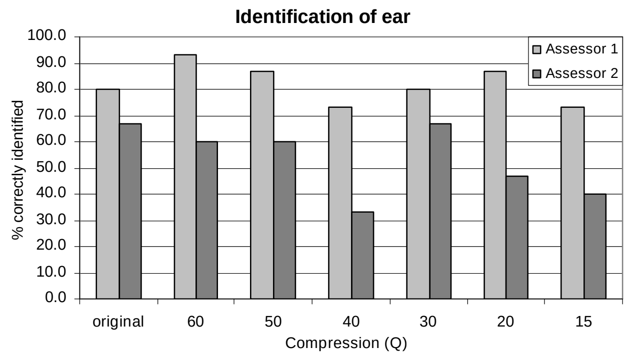


Figure 4: Percentage of correct identification of the ear (right or left) by the two assessors for the different compression rates.

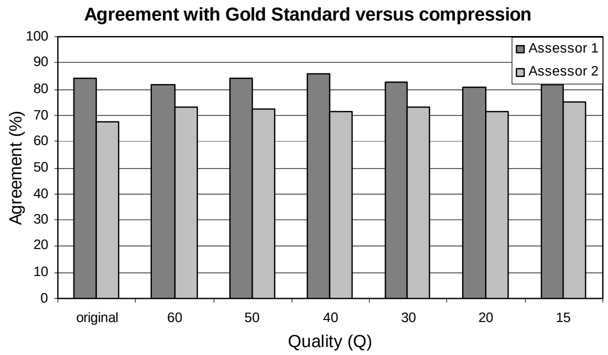
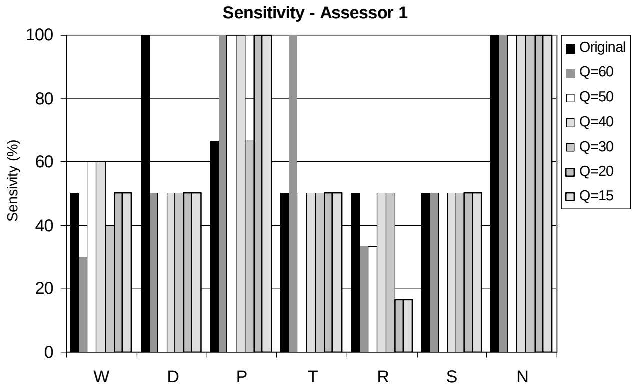
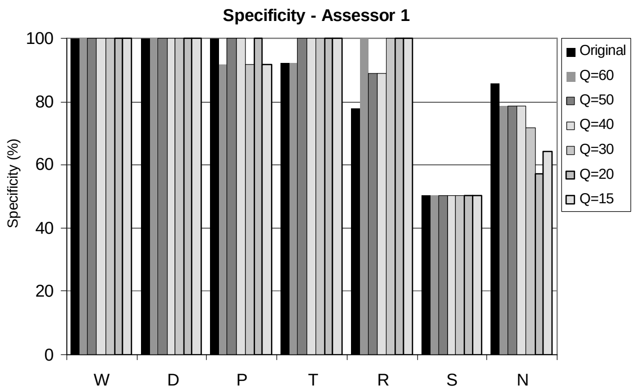


Figure 5: Agreement (%) between the assessors and the gold standard on the presence or absence of a clinical abnormality in the image.





Figures 6 to 7: Sensitivity and specificity for assessor 1 and for the different compression rates. W: wax, D: discharge, P: perforation, T: typmanosclerosis, R: retraction, S: serous otitis media, N: normal.

identified (right or left) by the assessors. Figure 5 plots the agreement between both assessors and the gold standard assessment of each of the conditions as shown in table 1. The sensitivity and specificity for assessor 1 only is plotted in Figure 6 and 7; sand in the ear canal is not shown as no assessor saw this in any of the images.

IV. Discussion

There is no definitive answer as to what RMS Error value is indicative of poor image quality, and so therefore the results can be used only to compare the relative effect of compression rate, and the effect of compression on the colour channels. Figure 1 demonstrates that although the effect on compression on each image is different (both on image size and RMS error), there is a similar trend for all images, with a

sudden rise in RMS error occurring at the higher compression rates. It would appear that there would be little benefit from compressing an image beyond about 20KB, when there is a sharp increase in cost of image quality.

As shown in Figure 2, the affect of compression is largest in the red channel, and least in the green channel. The error bars (+/- standard deviation) indicate a statistical difference between the results for the red and green channels, but not between the blue channel and either of the other two channels. The reason for the differing effects on the colour channels is yet to be explored, but can be probably be attributed to the reflective properties of the various structures recorded on the image.

As can be expected with many subjective assessments, the results in this study were affected by the differing interpretations and conceptions of various parameters and conditions by the individual assessors. This is shown clearly in Figure 3, where the assessor for the gold standard graded almost 50% of the original images as being of poor quality, whereas the other assessors found that the majority of the images were of good quality until at least Q=20. This indicates that the assessors had a different standard in mind for the grading the quality of otology images, and that future studies should include a session where image quality is discussed and descriptions are standardised. This could include the development of a set of criteria for factors such as the plane of focus and which features are clinically significant.

There is a poor rate of correct of identification of which ear was being viewed (figure 4), and there is no apparent relationship to the level of image compression. In a few situations (assessor 2, Q=40, 20 and 15) the rate was actually worse than 50%. It is very unlikely that image compression actually changes the image so much that it appears that the opposite ear is being viewed. A poor quality image may cause misunderstanding for inexperienced assessors, even which ear is being viewed. The ear is orientated at a lateral to medial angle to the ear canal from posterior to anterior, allowing determination of side.

The plots of agreement (Figure 5) and sensitivity and specificity (Figures 6 and 7) do not show any relationship between the ability to detect the presence or absence of an abnormality and the degree of image compression. The agreement is about 80% for assessor 1 and 70% for assessor 2. In most cases sensitivity and specificity remain relatively unchanged. However, sensitivity (the percentage of those with the condition positively identified by the assessor) is poor in most cases. On the other hand specificity (the percentage of the ears without the condition correctly identified by the assessor) is very good in most cases; only for serous otitis media and a normal eardrum was specificity poor. These data indicate that the assessors often missed the presence of a condition, and when taken with the knowledge that the gold-standard image quality was poor for almost 50% of the images, it can be concluded that image quality masked the presence of the conditions. Other factors may also have contributed such as the memory effect, or the experience of the assessor.

V. Conclusion

1. Images can probably be compressed to about 20KB from 1.44MB using JPEG compression, although further study of what clinically significant features and abnormalities are lost with image compression is required.
2. A good protocol for image assessment, with a session for assessors to standardise their definitions, is necessary for subjective assessments of the otology images.
3. Only images that can be graded a good or excellent should be used as an original set of images for future studies.
4. Further research is warranted into the reason for differential compression of the different colour channels.

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